

Utilizing Malaysian local ingredients in developing low-cost goat formulation: a modeling approach

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Expensive feed prices for ruminants farming is one of the main factors that slash the farmers' profit margin. The main reason is due to most pallets are imported from abroad. However, many local ingredients can also be used to produce cheaper pallets complete with the required nutrients, simultaneously the ability to use the sources of local plants. Hence, this study proposes a diet mix for ruminants that consists of the best combination of ingredients with specific quantities that fulfil nutritional needs using the mathematical modeling approach known as Linear Programming (LP). The ruminant that is the focus of this study is goat since this type of ruminant has a high market demand in Malaysia. As a result, the LP model generated an optimal solution at a minimum cost compared to the existing feed in the market. Only two ingredients have been chosen by the LP model which fulfils all nutritional needs at a very low-cost. This solution may be used by practitioners to assist in generating low-cost quality ruminant diets which able to increase profit margins among local farmers.

Keywords: Goat, feed mix, nutrients, optimization, cost minimization, Linear Programming.

INTRODUCTION

In Malaysia, the livestock industry is an integral part of the agriculture sector, particularly in providing employment for the population and supplying useful animal protein. The livestock industry in Malaysia is one of the main industrial sectors that boost the progress of national agriculture (Zayadi, 2021). Besides providing profitable employment, this sector caters to the internal demand for meat, milk, and dairy products.

The livestock industry slowly developed from 1996 to 2002, but displayed a steady growth between 2005 and 2012 because of government efforts and initiatives. The industrial growth ascertains food safety at national level and reduces reliance on meat imports (Kingombe and Di Falco, 2012). Nevertheless, the self-sufficiency rate for ruminants is still lower than 30%, mainly because the demand exceeds the supply of local producers. To meet at least 50% of the local market needs increasing the national livestock production, including ruminants, is imminent.

In light of ruminant production, the major issue faced by

breeders is feed that incurs massive cost of farming by 60-70% of the total cost (Hemme *et al.*, 2014; Swain, 2016).

Similarly, Alqaissi *et al.* (2011) reported that a moderate share of feed expenses was noted in most farms across Central and South America, Africa, Oceania, and southern areas of Europe, which reached at least 50-70% of the total expenses. The costly pallets are ascribed to the ingredients that are mostly imported from abroad, thus increasing the production cost in ruminant farming.

A wide range of ingredients can be given to ruminants for the production of quality pallets. However, the best combination of the ingredients should be determined to ensure that the feed fulfils all the nutrient requirements for ruminants. This combination is called feed mix or feed formulation. Feed formulation refers to the method that combines ration ingredients to provide livestock at distinct phases of manufacturing with the required nutrition. Feed formulation should ensure that all essential nutrients are included to sustain the needs, reproduction, and physiological health of the animals. The feed mix should promote easy digestion and have fewer environmental impacts (Saxena and Khanna,

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2017). It should also be palatable, digestible with permissible levels of anti-nutritional variables, and economical. An effective feed formulation model should generate the optimum combination of the ingredients at a minimum cost to meet all dietary demands of the animals.

The two main factors that must be considered when formulating quality pallets are suitable ingredients in the feed and nutritional requirements for the ruminant (Soong *et al.*, 2022). Suitable ingredients are crucial to produce high-quality pallets. Each animal should consume different feed types based on their digestion system. For instance, compared to other livestock, deer are selective in choosing green grass. Therefore, the list of suitable ingredients that meets the needs of ruminants must be identified to yield high-quality mixture of feed (Tixier *et al.*, 1997). Some of the important ingredients mentioned in the literature are soybean (Rahman *et al.*, 2020), alfalfa (Srisaikhram and Rupitak, 2020), paddy straw (Romero *et al.*, 2020), and maize grain (Pereira *et al.*, 2021). The use of agricultural waste as animal feed is beneficial for obtaining animal nutrients and reducing pollution (Al-Arif *et al.*, 2018). Notably, local plants (e.g., Napier grass and palm fronds) have been recommended as good ingredients for producing quality ruminant pallets at a low cost while concurrently maximising sources of local plants (Mat *et al.*, 2022).

Since feed takes up 60-70% of the total production costs, any effort to decrease feed costs will significantly minimise the total cost. Thus, a good combination of ingredients with specific quantities is required to produce a healthy diet that meets all nutritional needs, as different ingredients have different nutrients with specific functions. Therefore, this study proposes the combination of ingredients through the formulation of feed for ruminants, which can slash the cost by using local ingredients. The ruminant applied in this study is the goat, mainly due to its high market demand in Malaysia (Kaur, 2010).

MATERIALS AND METHODS

The four phases deployed in this study are problem identification, data collection, model development, and model evaluation. Figure 1 illustrates the process of the four phases and followed by the description of each embedded step. **Phase 1: Problem Identification:** The ruminant diet formulation is plagued by several constraints, including type of nutrients, suitable combination of ingredients that meets nutritional requirements and pallet processing cost. The information was retrieved from literature review, observation and interviews with experts.

Phase 2: Data Collection: Primary and secondary data were collected in this study. Primary data were gathered from interviews with experts in Veterinary Kedah, Malaysia as well as commercial breeders from Kedah and Perlis states. The participants were experienced in farming commercial ruminants involving more than 100 animals at once. The

interview sessions with breeders unveiled the fact that they preferred low-cost pallets at less than MYR 50/100 kg or 11.77 USD/100 kg consisting of sufficient nutrition for their ruminants.

As for secondary data, literature reviews and books were used as references. The required data included nutrient composition, ingredients for ruminants and nutrients required by the ruminants. The composition of nutrients in each ingredient and the appropriate ingredients for ruminants were obtained from the Malaysian Agricultural Research and Development Institute (MARDI) website and literature review.

Phase 3: Model Development: As mentioned earlier, the LP technique was deployed to determine the feed formulation model in the exact linear optimal solution. For the purpose of model formulation, relevant data were used to build the objective function and the constraints. The primary objective of this study is to minimise the total cost of feed mix in producing quality pallets for goats that satisfy all nutritional needs. The objective function is expressed in equation 1, as follows:

$$\text{Minimize Cost, } C = \sum_{i=1}^{11} c_i x_i \quad (1)$$

where $i = 1, 2, \dots, 11$

x_1 = Weight of Napier grass in kg; x_2 = Weight of silage in kg; x_3 = Weight of *petai belalang* in kg; x_4 = Weight of rice paddy straws (*jerami padi*) in kg; x_5 = Weight of wheat bran (*dedak gandum*) in kg; x_6 = Weight of soybean bran (*dedak soya*) in kg; x_7 = Weight of paddy bran (*dedak padi*) in kg; x_8 = Weight of anchovy head (*kepala bilis*) in kg; x_9 = Weight of corn silage (*silaj jagung*) in kg; x_{10} = Weight of soy dregs (*hampas soya*) in kg; x_{11} = Weight of palm fronds (*pelepah sawit*) in kg; c_i = Cost of ingredients i per kg

Subject to:

$$\sum_{i=1}^{11} c_i x_i \leq \text{MYR } 50 \quad (2)$$

$$\sum_{i=1}^{11} x_i \leq 100 \text{ kg} \quad (3)$$

$$7 \leq N_{k1} X_i \leq 14 \quad (4)$$

$$0.30 \leq N_{k2} X_i \leq 0.80 \quad (5)$$

$$0.25 \leq N_{k3} X_i \leq 0.40 \quad (6)$$

$$12 \leq N_{k4} X_i \leq 35 \quad (7)$$

$$X_1, X_2, \dots, X_{11} \geq 0 \quad (8)$$

k_1 = % of protein; k_2 = % of calcium; k_3 = % of phosphorus; k_4 = % of dry matter; k = Type of nutrient = 4; N_{ki} = Amount of nutrient, k (%), in ingredient i ; L_k = Lower limit of the total amount of nutrient, k ; U_k = Upper limit of the total amount of nutrient, k



Equation (2) was included to determine the least cost for feed mix, which refers to a maximum of MYR 50 per 100 kg. Next, equation (3) ensured that the total feed mix produced is 100 kg per packaging, as sold in the market. Meanwhile, equations (4-7) were applied to determine the nutrients comprising of protein, calcium, phosphorus, and dry matter, respectively. The LP model was then run in Excel Solver to yield the optimal solution.

Phase 4: Model Evaluation: The actual data obtained from the feed available in the market were used to compare with the model output to observe the performance displayed by the proposed model.

RESULTS

The primary objective of this study is to produce feed mix for ruminants at the lowest cost possible using a combination of local ingredients with complete nutrients. Referring to various sources, eleven ingredients and four nutrients were considered and inputted into the LP model. The ingredients with their price per kilogram are listed in Table 1, while the four nutrients are given in Table 2.

Table 1. Type of ingredients with their price.

Ingredients	Cost (MYR/Kg)
Napier grass	0.20
Silage	0.40
Petai belalang	0.018
Rice paddy straws	1.47
Wheat bran	1.50
Soybean bran	1.90
Paddy bran	1.00
Anchovy head	2.90
Corn silage	0.89
Soy dregs	0.25
Palm fronds	0.43

Table 2. Types of nutrients with their minimum and maximum requirements.

Type of nutrients	Min (%)	Max (%)
Protein	7.00	20.00
Calcium	0.30	0.80
Phosphorus	0.25	0.40
Dry matter	12.00	35.00

The minimum and maximum percentages of nutrients are important to ensure optimal growth of the goat. For instance, the ranges of nutrients for protein and calcium are 7.0-20.0% and 0.3-0.8%, respectively.

Model Solution: The optimal solution generated by the LP model is presented in Table 3, which tabulates the ingredients that provide the required nutrients. In fact, only two ingredients were selected for the proposed model, namely

Napier grass and petai belalang. The optimal cost for this feed formulation is MYR 14.97 (3.52 USD).

Table 3. Optimal solution obtained from the linear programming model.

Ingredients	Weight (kg)	Cost (MYR/kg)
Napier grass, x_1	72.34	0.200
Petai belalang, x_3	27.66	0.018
Optimal solution	100.0	14.97

Based on the two ingredients used in the model, the objective function is calculated as follow:

$$\begin{aligned} \text{Minimize Cost, } C &= \sum_{i=1}^{11} c_i x_i \\ &= (0.20 \times 72.34) + (0.018 \times 27.66) \\ &= \text{MYR } 14.97 \end{aligned} \quad (1)$$

This LP model shows that the cost of producing the pallets is MYR 14.97 (3.52 USD), which satisfies the constraint in equation (2) with a cost of less than MYR 50. Next, the constraint in equation (3) is satisfied because the total weight of the feed mix is 100 kg (see Table 3). The amount of four nutrients considered in the feed composition is presented in Table 4.

Table 4. Composition of nutrients in the feed mix model solution.

Types of nutrients	Min (%)	Max (%)	Solution (%)
Protein	7	20	18.6
Calcium	0.30	0.8	20
Phosphorus	0.25	0.4	0.32
Dry matter	12	35	0.31

The solution provided by the LP model satisfied all the four nutrients expressed in equations (4-7), as the generated values fell within the range of minimum and maximum requirements.

Model Evaluation: Observation was made by comparing the proposed feed mix with feed available in the market. The feed price is mostly ~ RM50 (11.77 USD). The comparison made between the feed types obtained from the practitioners in the field using the trial-and-error method in an Excel spreadsheet exceeded MYR 50 for 100 kg of feed.

DISCUSSION

Eleven (11) ingredients and four (4) nutrients were taken into consideration in developing the LP Model. Amongst all ingredients, only two ingredients have been chosen to produce the optimal diet for ruminants. The combination of 72.34% napier grass and 27.66% petai belalang gives the optimal solution with MYR 14.97, and fulfills all the four nutrients considered in this study. This evidenced that the solution obtained from the LP model is viable to produce feed mix at a minimum cost, while concurrently satisfying all nutrient



requirements and using local ingredients. Hence, the study objective has been successfully achieved. Finally, the model evaluation has been made by comparing the solution with other available feeds. The model revealed that the LP model had successfully generated the optimal solution that was cheaper than other feeds, which successfully addresses real problems. Further experimentation is needed to evaluate the effects of ruminant growth and their health such as research by Chanjula (2018) which substitute crude glycerin as an energy source in goat diet.

Conclusion: This study sought the best combination of ingredients to produce a quality feed mix at the lowest possible cost. The LP method was deployed to fix the feed formulation problems for ruminants, particularly goats. As a result, the best combination of ingredients for ruminant feed that meets all the required nutrients at a minimum cost was generated. This study demonstrates the practicability of the developed LP model as an effective tool for yielding optimal solutions in feed formulation problems. This method can support practitioners in producing high-quality feed formulation at a minimum cost.

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